Monitoring the Life Cycle of the Northern Quahaug, *Mercenaria mercenaria*, in Prince Edward Island.

T. Landry[1], M. Hardy[2], M. Ouellette[1], N.G. MacNair[3] and A. Boghen[2]

[1]Department of Fisheries and Oceans
Gulf Fisheries Centre, Science Branch
P. O. Box 5030
Moncton, New Brunswick
E1C 9B6

[2]Département de biologie
Université de Moncton
Moncton, New Brunswick
E1A 3E9

[3]Department of Fisheries, Aquaculture and Environment
P.O. Box 2000
Charlottetown, Prince Edward Island
C1A 7N8

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[1]Department of Fisheries and Oceans
Gulf Fisheries Centre, Science Branch
P. O. Box 5030
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[2]Département de biologie
Université de Moncton
Moncton, New Brunswick
E1A 3E9

[3]Department of Fisheries, Aquaculture and Environment
P.O. Box 2000
Charlottetown, Prince Edward Island
C1A 7N8

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ABSTRACT

Landry, T., M. Hardy, M. Ouellette, N.G. MacNair and A. Boghen. 2001. Monitoring the life cycle of the northern quahaug *Mercenaria mercenaria* in Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. 2355: v + 18 p.

In Prince Edward Island, the northern quahaug is at its geographical distribution limit. This translates into a shorter growth season and, therefore, longer times to reach the minimum harvestable size than its southern counterparts. Nonetheless, the quahaug is an important fishery resource for the region. A decline of quahaug stocks has spurred research into the possibility of enhancement. A clear understanding of quahaug productivity, is however a prerequisite. Accordingly, temperature and quahaug condition indices were monitored in both subtidal and intertidal zones. There were small differences in these parameters between these two zones in that quahaugs tended to condition slightly better in the subtidal zone. Larvae were also sampled throughout the season. Quahaug larvae were absent with the exception of one sampling date and even then were only at very low concentrations (0.085 larvae /L). A recruitment experiment, consisting of sediment trays with a combination of treatments (netting and gravel), was conducted. Abundance of quahaug recruits averaged only 0.778 quahaugs /m². Statistical analyses showed no significant differences in recruitment between treatments, while there was a difference between sites. A population survey of the study area suggested that recruitment is low (0.444 quahaugs /m²). Such poor productivity may be attributable to low broodstock densities and, therefore, weaker fertilization rates. Enhancement may be an important approach in sustaining or improving quahaug fishing activities.

RÉSUMÉ

Landry, T., M. Hardy, M. Ouellette, N.G. MacNair et A. Boghen. 2001. Monitoring the life cycle of the northern quahaug *Mercenaria mercenaria* in Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. 2355: v + 18 p.

Le quahaug nordique est à sa limite de distribution géographique à l'Île-du-Prince-Édouard. Ceci implique une réduction dans la période de croissance et donc augmente le temps nécessaire à atteindre la taille minimale de vente comparée aux quahaugs du sud. Néanmoins, le quahaug représente encore une ressource importante dans la région. De même, la diminution de ses stocks a incité les chercheurs à trouver des méthodes pour améliorer les stocks. Ceci exige premièrement d'avoir une compréhension précise quant à la productivité du quahaug dans ce climat. La température et les indices de condition des quahaugs ont été évalués en fonction de la zone intertidale et la zone subtidale. Des petites différences ont été observée dans ces derniers paramètres entre ces deux zones. Les quahaugs en zone subtidale avaient un indice de condition légèrement plus élevé. Des larves ont aussi été prélevées au cours de la saison. Les larves de quahaug ont été observées à seulement une date d'échantillonnage et à basse concentration (0,085 larves /L). Le recrutement a été évalué suite à une expérience qui consistait de pièges à sédiment avec une combinaison de traitements comprenant des filets et de la gravelle. Ces traitements n'ont pas eut d'effet significatif sur le recrutement alors qu'il y a eut une différence significative pour le site. En moyenne, les abondances de recrues étaient seulement de 0,778 quahaugs / m². Un recensement de la population de quahaug dans l'aire d'étude a signalé une densité de recrues de seulement 0,444 quahaugs / m². Cette pauvre productivité est peut-être attribuable aux densités faibles des adultes et par conséquence des taux de fécondation réduites. L'amélioration des stocks risque de devenir une approche importante pour maintenir ou augmenter la pêche du quahaug.

Introduction

This report is part of an ongoing research program initiated by the Department of Fisheries and Oceans, its provincial counterpart, the Prince Edward Island Department of Fisheries and Tourism as well as l'Université de Moncton. These institutions, in collaboration with shellfish growers, display continuing interest in the development of the northern quahaug *Mercenaria mercenaria* fishery in Prince Edward Island (PEI).

Quahaugs are a very attractive candidate species in terms of economic development as a food item. They are among the most valuable shellfish species in the Maritimes and are in high demand in national and international markets (Gates 1993). Their shells are strong enough to withstand shipping, their shelf life in refrigeration can be several weeks and in addition to these marketing characteristics, they are in high demand.

There are, however, limitations and challenges for the developing quahaug industry. Quahaugs have a slow growth rate. In fact, it may take from 4 to 13 years to reach the minimum legally harvestable size of 50 mm in the Canadian climate (Landry *et al.* 1993, Landry unpubl.). Quahaugs are susceptible to predation by crabs, and many other species, until they reach a size of approximately 30 mm (Bricelj, 1993). Moreover, in recent years, quahaugs are rarely found at high densities in PEI while landings have remained relatively unchanged. This, however, more likely reflects transfers of quahaugs from closed sites, in contaminated areas, followed by a depuration period in a clean area. These transfers, rather than a sustainable fishery from a given area, are perhaps the reasons for the stability of landings. Harvesting from closed areas can be viewed as a postponement of a declining stock problem.

Current stock management practices in PEI are based on a minimum harvestable size (50 mm). This ensures that a portion of reproductively-active quahaugs will remain in the population and contribute to the future recruitment cohort. However, recent research on quahaugs (Landry *et al.*1999), as well as other species (Levitan 1991; Benzie and Dixon 1994; Babcock and Keesing 1999), suggests that this may be insufficient to sustain the level of effort from the fishing industry.

In most invertebrate species, reproductive effort is positively correlated to body size. In 1998, several aspects of quahaug reproduction were studied in relation to shell length. Landry *et al.* (1999) showed that quahaugs only became sexually active at 25 mm and 30 mm for males and

females respectively. They also observed that the percentage of gonad tissue increased with shell length. In effect, they found that the gonad makes up approximately 6% of a 30 mm quahaug, while it constitutes 60% of an 80 mm quahaug (Landry *et al.*1999). This relationship illustrates the important difference in contribution between small and large quahaugs in terms of gamete production. In addition, there is also no indication of reproductive senility in older quahaugs (Peterson 1986). Furthermore, large quahaugs tend to produce slightly larger eggs than smaller females (Landry *et al.*1999; Bricelj and Malouf 1980). Large eggs are shown to have higher energy reserves and consequently produce larvae with greater survival rates (Kraeuter et al. 1982). In addition, the productivity of these molluscan populations is affected by increasing environmental stress from coastal activities.

Another important facet of quahaug biology that needs to be assessed, for developing a sustainable industry, is stock replenishment. Quahaugs removed from less intensive fishing areas can be replaced naturally by the newly setting spat produced in adjacent localities. In heavily harvested areas though, stock replenishment may need enhancement such as the seeding. Hatchery-produced quahaugs, however, requires significant manpower and cost. Generally, this hatchery production can be an economically viable option in a commercial situation but less so in the context of a recreational fishery (MacFarlane 1998).

Alternative methods for enhancing stocks are being explored. Such new techniques could be based on an improved understanding of natural events in the quahaug, in order to increase and harness productivity, through relatively low-level interventions. This type of "low-cost" manipulation could prove to be valuable for both recreational and commercial fisheries. Many other aspects, for improving the quahaug fishery, are currently being addressed by various institutions. The selectively bred variety of quahaug, *Mercenaria mercenaria notada*, is being evaluated because of its higher growth rate. Other studies include survival and predator exclusion techniques through the use of bags, oyster trays, netting, pea gravel, etc.

The goal of this project is to help provide a comprehensive understanding of quahaug productivity in its northern geographic limit and contribute valuable information for purposes of enhancement. Accordingly, this project examines life cycle events by monitoring temperatures, condition indices, larvae, recruitment and population structure while placing emphasis on the large highly productive quahaugs.

Materials and methods

Study area

Experimental work for this project was conducted in West River, located on the south shore of PEI near Charlottetown, from June to October 1999 (Figure 1). Historically, West River was a highly productive area for quahaugs. However, there were significant stock loses attributed to the construction and subsequent removal of a causeway.

Condition index

In June 1999, approximately 2000 quahaugs of the chowder size class (>75 mm) were purchased, from the PEI Shellfish Association, for condition index analyses. They were marked by scoring an "X" in the shell with an electric grinder in order to easily identify the quahaugs. They were then placed randomly in intertidal and subtidal zones on the private leases of shellfishers in West River. Triplicate plots (sites A, B and C) were established for each zone for a total of 6 plots. Plots in the intertidal zone were placed at 1 m below high water, based on average tides, while subtidal zone plots were placed at 1 m below low water. Therefore, intertidal plots where exposed to the air for approximately 2 h every tidal cycle while subtidal plots might have been exposed twice for only a short period during the entire season. Each plot was marked by bricks and buoys as well as identified by its GPS (Global Positioning System) co-ordinates. It was then seeded with 300 quahaugs at a density of $100/m^2$.

Samples were collected by hand at low tide or with tongs at high tide. Ten (10) quahaugs were collected every 10 days from June 16th to July 26th from each of the 6 plots, then at increasing intervals until October 31st.

Condition indices were calculated by weighing the dry organic material of a quahaug in relation to its dry shell weight.

$$C.I. = (organic\ tissue\ weight \times 100 / shell\ dry\ weight)$$

The organic tissue weight is the result of the dried tissue weight minus the ash weight. Tissue samples were dehydrated at 60°C for at least 24 hours prior to weighing. The dried samples were then ashed at 500°C for 24 hours or until all organic material was removed. Shells were rinsed and allowed to air-dry for at least 4 hours before weighing.

Temperature monitoring

Temperature probes (Vemco) were placed in both intertidal and subtidal waters. They were attached to bricks and placed flush to the sediment. Temperatures were recorded every hour from June 25th to October 31st.

Larvae

Plankton tows were conducted at 3 locations, approximately 1 km apart, in West River. A plankton net with a 25 cm diameter was towed at low speed for 2 minutes to collect all samples. Samples were taken at two week intervals from July to September

Samples were placed in 500 ml bottles and fixed with a 5% buffered formaldehyde solution. Larval species were identified and counted under a light microscope.

Recruitment

A recruitment experiment was undertaken at 3 sites. All sites were in place by July 7th. Each site had a grid consisting of a 4 m x 3 m wooden tray placed intertidally and inset to the sediment in order to have equal levels of substrate inside and outside the tray (Figure 2). The trays were subdivided into 12 squares (1 m^2) and had a Geotextile™ bottom to retain the sediment. The sediment placed in all of the trays was sifted through a 2 mm mesh. A control and three treatments were tested in triplicates in each tray (Figure 2). The control consisted of only sifted sediment, while in addition to the sediment, treatment 1 had predator netting, treatment 2 had gravel and small rocks, and treatment 3 had gravel and small rocks as well as predator netting.

Trays were left until late-October when the water temperature dropped below 10°C. Then the contents from each treatment (square) was individually bagged and taken to the laboratory for analysis. Each sample was carefully sifted by hand and the quahaugs counted.

Statistical analyses for the recruitment study consisted of a Nested (hierarchical) Analysis of Variance (ANOVA). Null hypotheses were that there would be no significant differences between treatments or sites. A thresholds of α (1) = 0.05 was used as it is a common value for biological studies (Zar 1996).

Survey

On June 2nd 1999, a survey consisting of 9 transects that were perpendicular to the shoreline and separated by a minimum of 250 m was conducted. Three samples from different water levels (high, medium, low) in the intertidal zone were collected from each transect for a total of 27 samples. A steel ring with an inner surface area of 0.25 m^2 was employed to delimit and ensure identical sample sizes. The animals inside the ring were removed by vacuuming the sediment into a bag with a Venturi pump. The samples were sorted and the quahaugs counted and measured.

Results

Temperature monitoring

Temperature profiles in intertidal and subtidal zones are presented in terms of daily averages in Figure 3. Seasonally, the average temperatures for intertidal and subtidal zones were 18.52°C and 18.27°C respectively. There was also more variation in the daily temperatures in the intertidal than the subtidal zone. Daily temperature ranges were wider in the intertidal zone (6.21°C) than those in the subtidal zone (2.21°C). Average water temperatures peaked at 24°C in mid-to late-July, then fluctuated around 20°C until mid-September after which it began to decrease. Temperatures reached 10°C in mid-October and were continuing to drop when the probes were removed in late-October.

Condition indices

Collectively, the condition indices for quahaugs varied little among sites. There were no significant differences in condition index between intertidal and subtidal zones (Figures 4, 5 and 6), although the quahaugs in the subtidal zone tended to have a slightly higher indices. Error bars (Figure 4, 5 and 6) represent the confidence interval. Maximum values (index = 3.4) were reached in mid to late-June while minimum values (index = 2.0) for all sites were observed in late-July. This represents a change of 40% in the condition index. Thereafter condition indices

fluctuated while tending to increase until mid to late September, when they became relatively stable (index = 2.8).

Larval studies

Low levels of quahaug larvae were recorded in the plankton analyses. In fact, quahaug larvae were absent with the exception of the August 11th sampling date where concentrations of were of approximately 0.085 individuals / L (1 quahaug per 10 L). Other species were found in varying concentrations throughout the season with the highest abundance of larvae observed being of razor clam *Ensis directus* with a concentration of 0.14 / L.

Recruitment

Quahaug spat, usually measuring from 3 to 5 mm in shell length, were found at all three sites. Statistical analysis by Nested ANOVA detected no significant difference between the treatments ($F = 0.694$; $p_{(\alpha(1)11,22)} > 0.7306$). The test, however, did show a significant difference between sites ($F = 6.433$; $p_{(\alpha(1)2,11)} < 0.01141$). Densities varied from 0 to 1.416 quahaugs /m² with an average of only 0.778 quahaugs / m². In comparison, softshell clams densities were also evaluated at one site, they were present at an average density of 40.0 / m².

Survey

Quahaugs were observed in 8 of the 27 samples. Seventeen quahaugs were found varying in size from 5.53 mm to 78.22 mm. The average quahaug density was of approximately 2.52 quahaugs/ m². Among the quahaugs present, 1.01 quahaugs / m² (41%) were under 30 mm in size. Recruits (< 10 mm) in the survey analysis were present at a density of 0.444 quahaugs / m² (18 %). Quahaugs were not distributed equally in relation to their tidal heights in the intertidal zone. In fact, they were present in the high, medium and low samples at 0 %, 18 % and 82% respectively.

Discussion

Temperature

Temperature is an effective tool for monitoring because it is one of the most important factors regulating quahaug metabolism (Rice 1994). It also coincides with seasonal changes of primary production and, therefore, food for bivalves. The profiles illustrated in fig. 2, for the most part, indicate similar variations in temperature between intertidal and subtidal zones. The daily minimum and maximum temperatures vary to a greater extent in the intertidal zone than in the subtidal zone. The higher variation in the intertidal zone reflects the time quahaugs spend exposed to the air and the elements (i.e. sunlight). Temperatures of 20°C were reached in late-June and in early July for the intertidal and subtidal zones respectively are important in stimulating spawning events in quahaugs (Rice 1994). In contrast, temperatures of 10°C or less, observed in mid-October, should initiate a period of inactivity and dormancy for the winter (Rice 1994).

Spawning

Condition indices are another widely used technique for evaluating the health and spawning activities of bivalves (Rainer and Mann, 1992), because they reflect the changes in the variation in the relative amount of organic matter. Seasonally, most of this variation is due to the production and loss of gametes during reproductive cycle.

Figures 4, 5 and 6 illustrate the seasonal variation in conditioning. The reductions in the indices from late-June to late-July are most likely the result of a major spawning event for quahaugs in PEI. This event brought on a drop in the condition index averaging 40% and corresponded with water temperatures of 20°C. However, spawning continued for at least a month followed by fluctuations in the condition index throughout the season. This may suggest that quahaugs in PEI "trickle" spawn. Such a drawn-out spawning cycle would further reduce fertilization rates by lessening chances of gametes meeting.

Although there were no significant differences between intertidal and subtidal zones at any of the sites, quahaugs tended to have slightly higher condition indices in the latter. The similarity in condition indices obtained in both zones is important information for enhancement work that will be discussed below.

Larvae

The presence of quahaug larvae in mid-August corresponds approximately to the anticipated spawning activities which occurred throughout July. Quahaug larvae generally spend approximately 2 weeks in the water column before setting (Rice 1994). Therefore, the larvae present are likely the result of spawning in late-July. It is not fully understood, however, why there were no quahaugs observed on other dates or why larval concentrations seem low. High variability in abundance of other species of molluscan larvae was also observed in the samples. Therefore, the absence of quahaug larvae in most samples may be due, at least in part, to this same variability. It may be possible to obtain more precise information on larval presence and concentration with a more extensive sampling program. This is the first attempt at monitoring quahaug larvae in West River and may prove to be very important as a baseline study.

Recruitment

Treatments in the recruitment experiment were based on two of the most common methods of protecting hatchery-produced seed. Netting and gravel are meant to reduce a predator's access to the seed, thereby reducing predation loses. Since all sediment was sifted to remove all animals, quahaugs observed in the trays were the result of this season's spat.

Statistical analyses revealed that the site had a significant effect on level of recruitment while the different treatments (netting, gravel and their combinations) did not. This does not mean that these treatments are without merit, they might still prove to be useful. They have proven to be beneficial in other studies (Flagg and Malouf 1983) where they played a role in the reduction of predation in seeded quahaugs. It is important to know that sediment type, hydrodynamics or biotic interactions associated to sites site had more influence on recruitment than local differences (i.e. gravel) in this study. The impact of these other factors should be studied further in order to identify important recruitment sites.

The average density of 0.778 quahaugs / m^2 is low when compared to other species such as the softshell clams which were present in densities of 40.0 / m^2. This may reflect the "normal" amount of recruitment by quahaugs in the area or it may be due to an underlying problem in the river, such as a low productivity, a low number of larvae reaching the site or low survival. Whichever the case may be, recruitment of approximately 1 individual /m^2/year (before factoring for mortality until harvestable size) is insufficient to support current fishery levels.

Survey

The survey showed similar results to those of recruitment analysis. The distribution of sizes as well as their frequencies is important for understanding productivity. Of the 17 quahaugs found, approximately 59 % had reached a sexual maturity (> 30 mm). This percentage would be encouraging if it was not for the low densities. Market size quahaugs (>50 mm) are present at a density of 1.19 quahaugs / m^2, which again is very low.

The majority of quahaugs (82%) were found in low (deeper) sites along the transects. All the recruits (<10 mm) were observed in low sites at an average density of 0.444 quahaugs/ m^2. This is in contrast with the findings of the recruitment study where densities were higher (0.778 quahaugs / m^2), and where the tidal height of the plot was comparable to the "high" survey samples. This inconsistency is likely the result of seasonal differences in survival. The lack of recruits in the high intertidal zone in June may be due to winter/ice mortality. The quahaugs observed in the recruitment study were recruits from the 1999 spawning event that had not yet been exposed to winter.

Enhancement

The results of this study suggest that enhancement may become very important if the fishing activities of the quahaug, in this area, are to be sustained or improved. One concept that is currently being investigated is the application of a reproductive sanctuary. Such a sanctuary would entail harnessing the natural fecundity of quahaugs in order to increase productivity by modifying their population structure in a small area (perhaps 10 m x 10 m). These interventions would only consist of an optimisation of the reproductive parameters, such as animal size, density, exposure to food and degree days.

This study and others (Walker and Heffernan 1994; Landry *et al.* 1999) suggest that the subtidal zone has advantages over the intertidal because of biological factors such as conditioning, but even more so in terms of socio-economic values. Quahaug fishers tend to concentrate their efforts in the intertidal zone where harvesting is more accessible. Therefore, sanctuaries in the subtidal zone would minimize any disruption on public grounds and in lease areas.

Broodstock would likely consist of large highly productive quahaugs and could be established in the subtidal zone at optimal densities for fertilization. Higher fertilization rates would, in turn, lead to the production of more larvae and hopefully improved recruitment.

Moreover, the effect of broodstock stocking densities and fertilization rates are currently being studied in the context of a sanctuary. These factors are important because even if sufficient broodstock is present, the distance between spawning adults may limit their fertilization rates. When bivalves spawn, their gametes immediately begin to disperse into the water column. With increasing distance between broodstock, the chance of an egg meeting and being fertilized by sperm decreases exponentially. Even minute distances can have a marked effect on fertilization. Pennington (1985), for example, showed that fertilization rates of sea urchins (*Strongylocentrotus purpuratus*) could be lower than 10 % with 1 m separation between the spawning pair. This illustrates clearly the need for more research into fertilization rates of the quahaug.

Conclusions

The integration of the information in this report, as well as that from ongoing work in this research program, strongly suggests the importance and significant potential for effective enhancement of the quahaug in PEI. Impacts of this work as well as others will be forthcoming.

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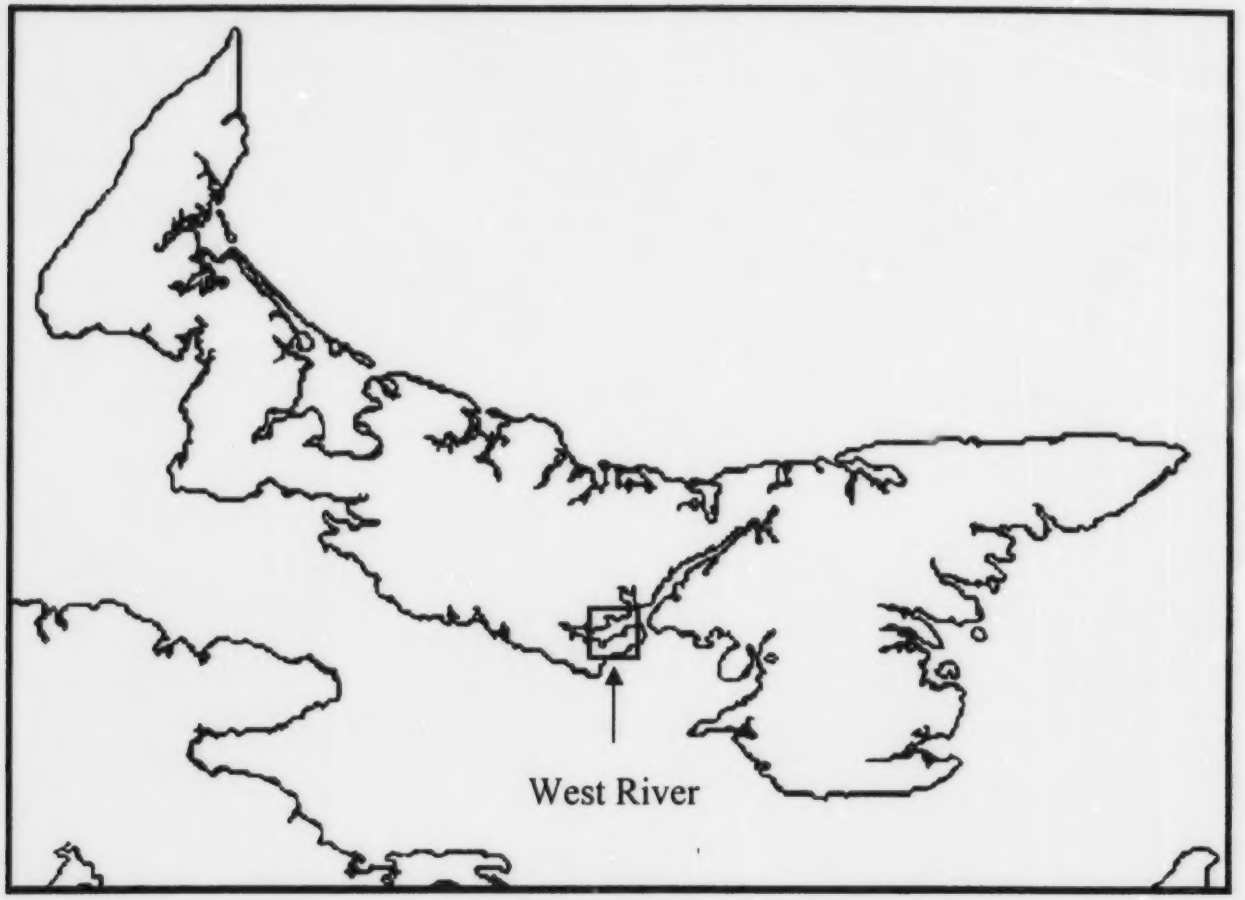

Figure 1: Location of West River, Prince Edward Island

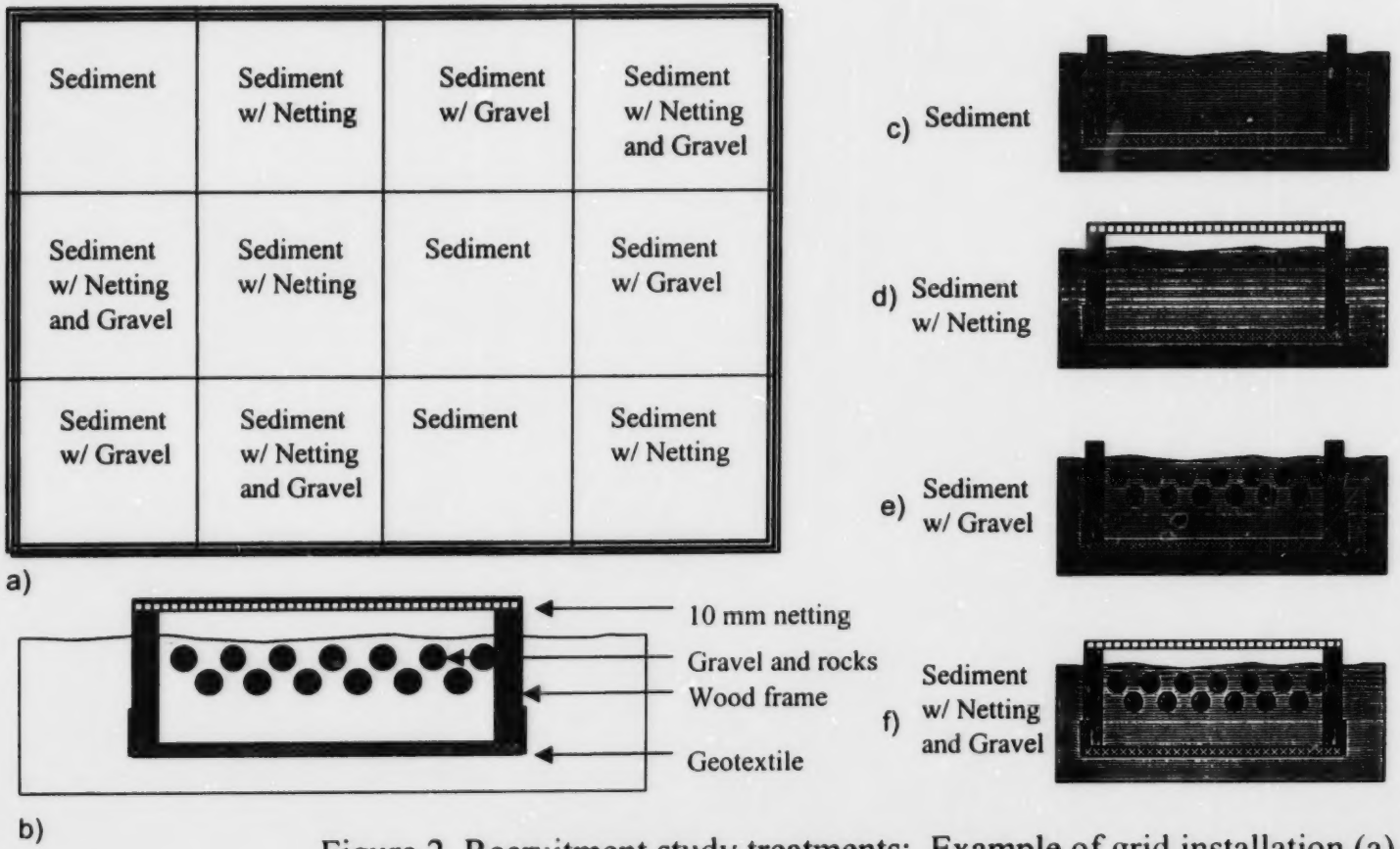

Figure 2. Recruitment study treatments: Example of grid installation (a) Details of installation (b) Treatments (c, d, e, f)

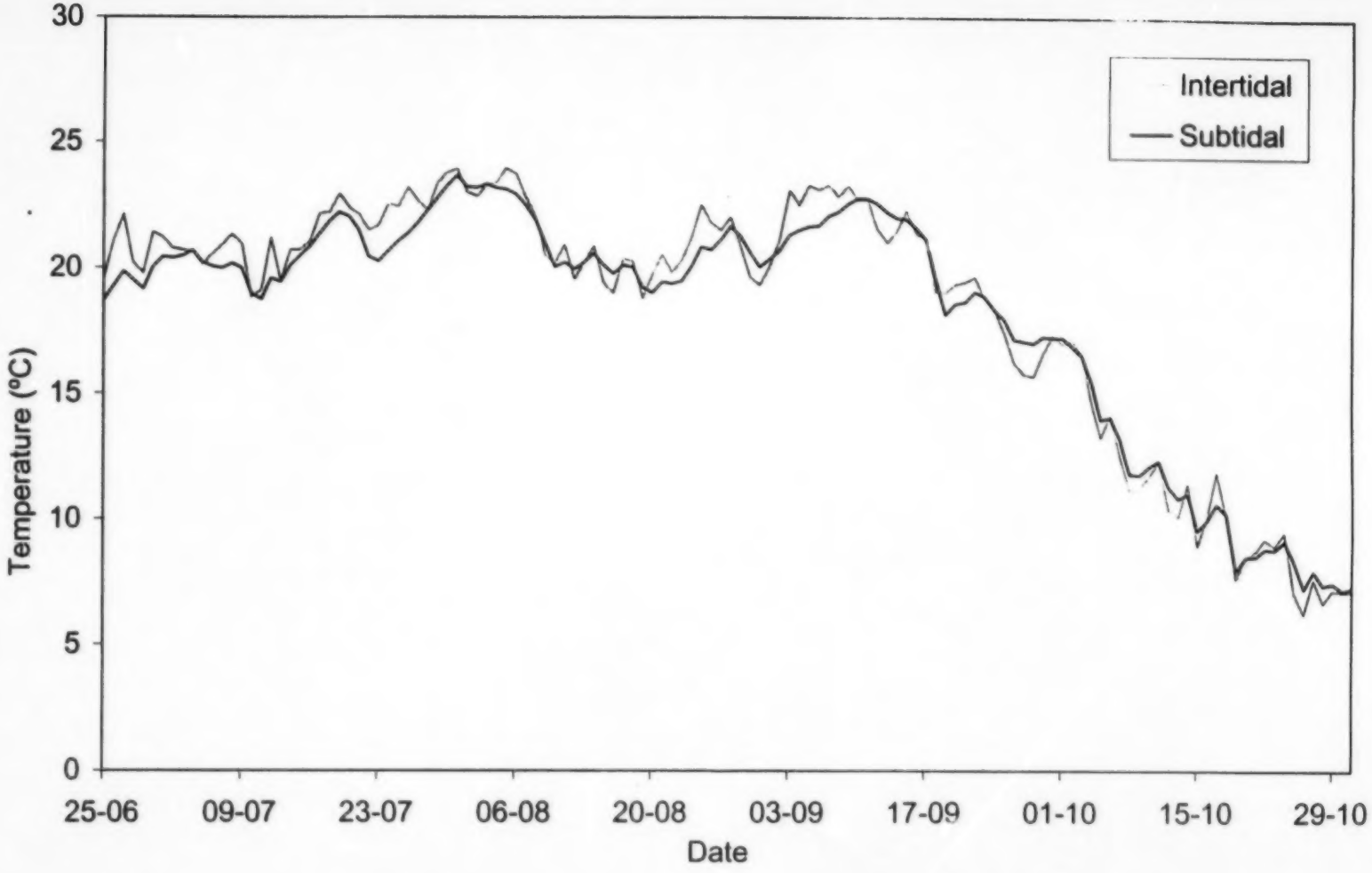

Figure 3. Temperature profiles for the intertidal and subtidal zones in West River, PEI from June to October1999

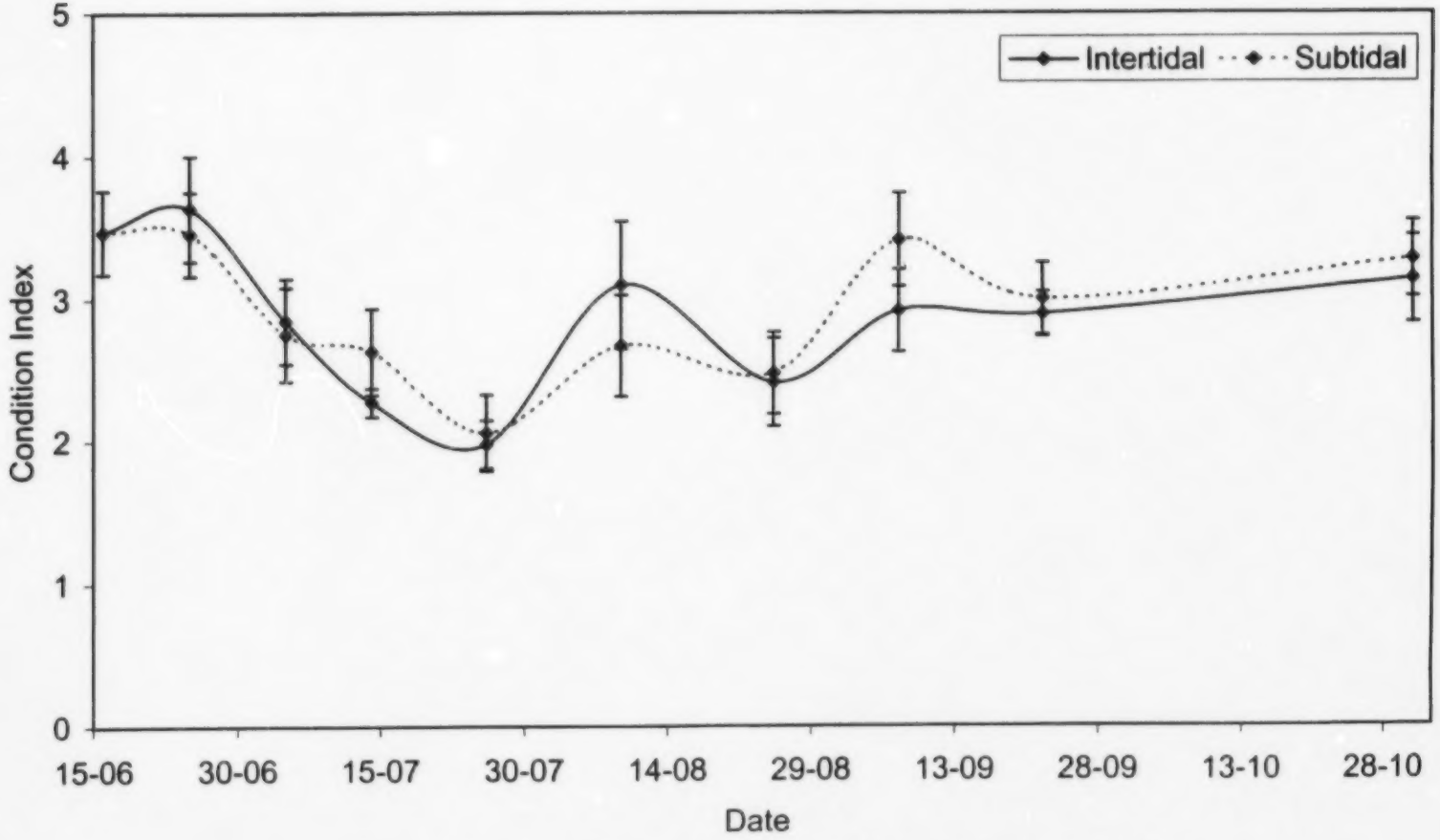

Figure 4. Seasonal condition indices of quahaugs at site A
(Error bars represent confidence intervals)

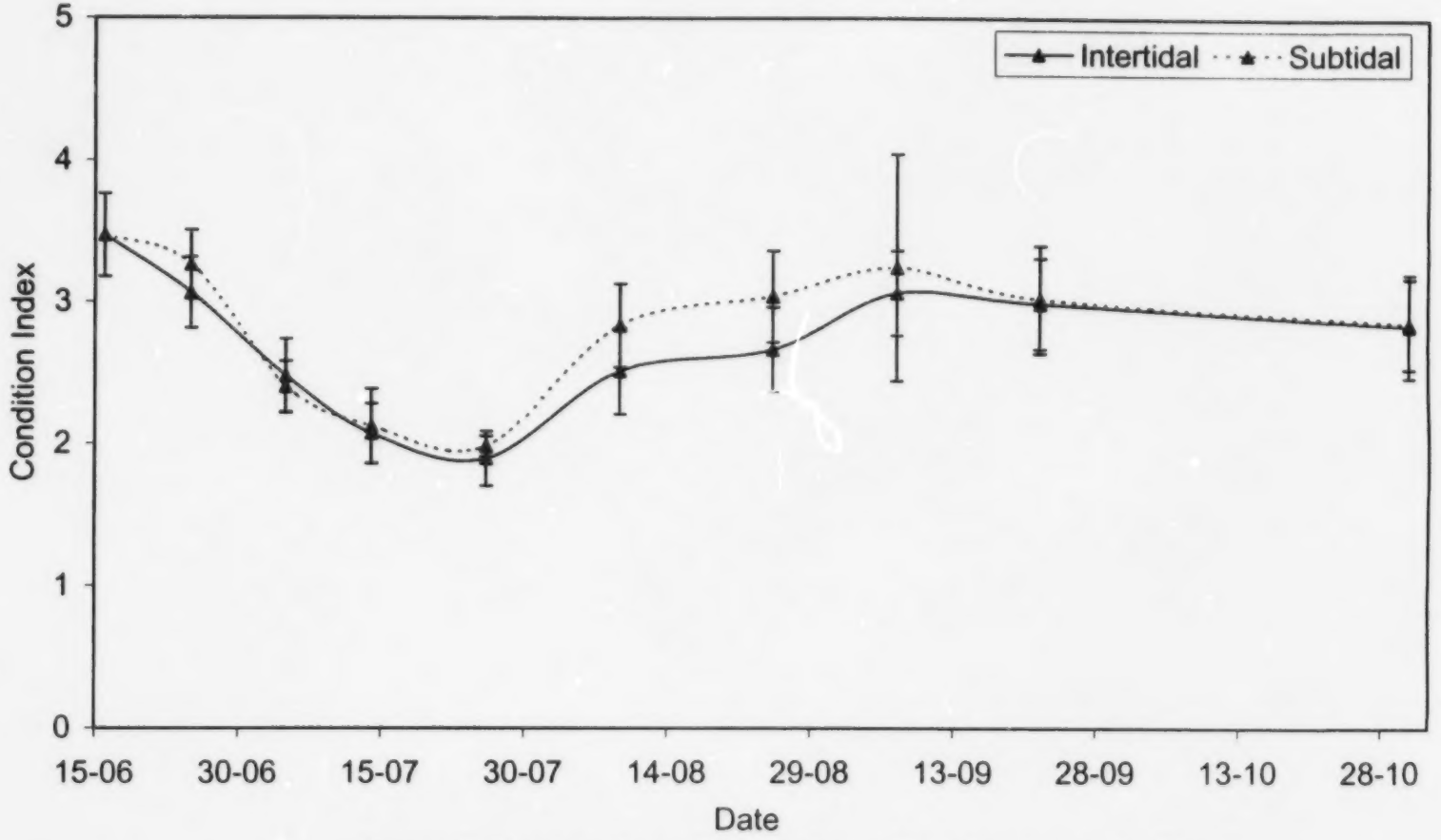

Figure 5. Seasonal condition indices of quahaugs at site B
(Error bars represent confidence intervals)

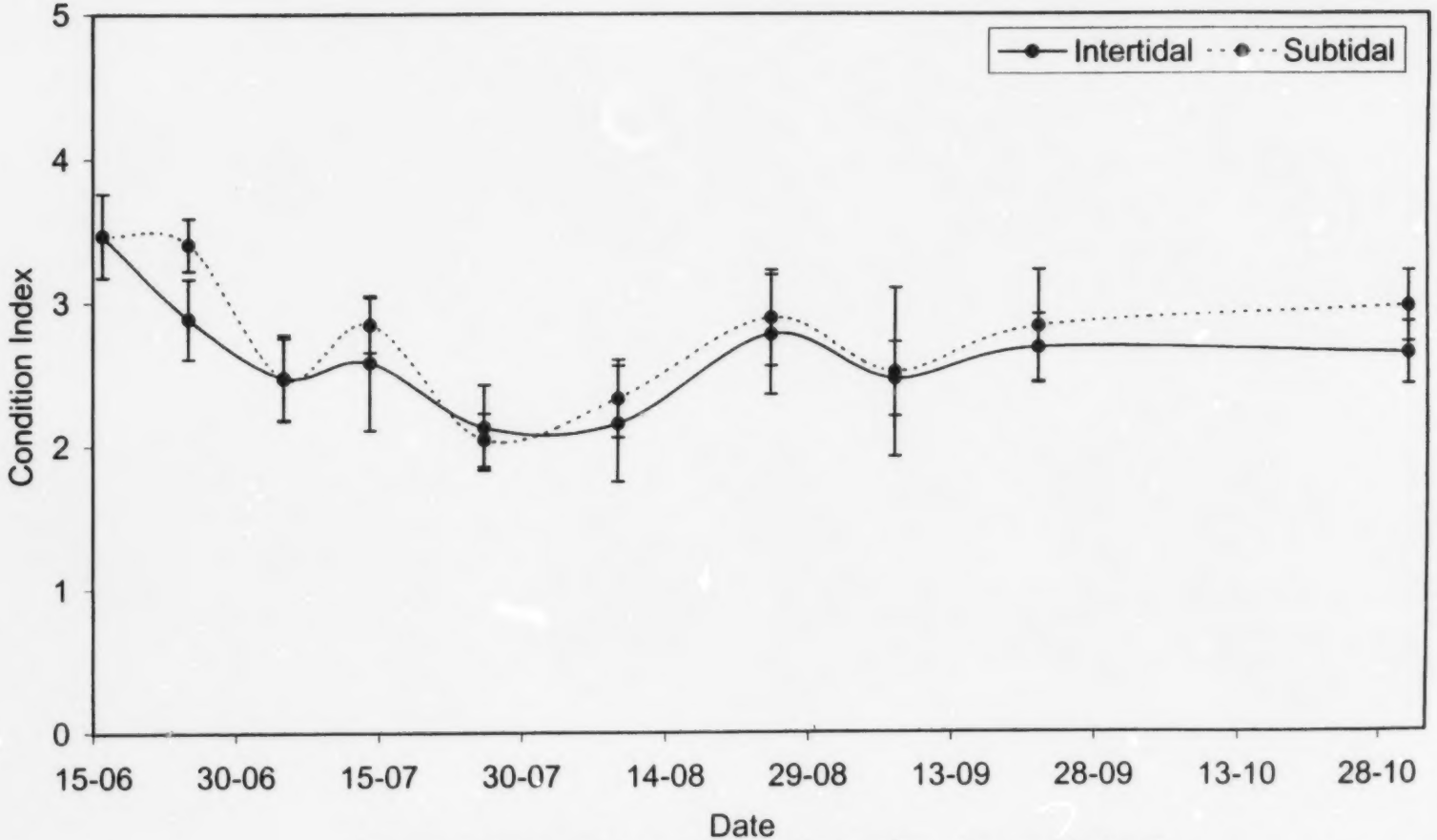

Figure 6. Seasonal condition indices of quahaugs at site C
(Error bars represent confidence intervals)